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MEMBRANE WATERPROOFING APPLICATIONS IN NEW YORK SECOND INTERIM REPORT

TECHNICAL REPORT 34
JUNE, 1978

materials
bureau
technical
services
subdivision

78-6

MEMBRANE WATERPROOFING APPLICATIONS IN NEW YORK

2nd Interim Report

Conducted in Conjunction with
The U.S. Department of Transportation
Federal Highway Administration
National Experimental and Evaluation Program (NEEP) No. 12
Bridge Deck Protective Systems

prepared by
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June, 1978
(Technical Report 34)

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ABSTRACT

Preformed sheet and liquid membrane waterproofing systems are being evaluated for use in concrete bridge deck rehabilitation work. The function of these membranes is to reduce the corrosion of reinforcing steel by providing a waterproof barrier between an existing concrete deck and a bituminous concrete overlay wearing surface.

This report describes the performance of five membrane systems after one year in service. Three of these are proprietary preformed sheets (Heavy Duty Bituthene; Royston Bridge Membrane No. 10; and Protecto-Wrap M-400A); one is a proprietary liquid system (NEA-4000 LT); and one is a non-proprietary bituminous epoxy membrane waterproofing. Each of these membranes was installed on a test structure in 1976 and overlaid with a 2½ inch thick bituminous concrete wearing course.

On the basis of visual observations, and electrical resistance and corrosion potential tests, all of the membranes, except for the bituminous epoxy system, are performing satisfactorily after one year in-service. The bituminous epoxy membrane appeared to be permeable when it was first installed. The first year's survey indicates no improvement in performance and the effectiveness of the bituminous epoxy as a waterproofing membrane is questionable.

CONTENTS

I. INTRODUCTION

Background

Bridge deck deterioration is recognized as a serious problem in New York. Although other factors contribute, the major cause of deterioration is due to chloride ions from de-icing salts which penetrate the concrete and cause corrosion of the reinforcing steel.

Waterproofing membranes are proposed as a solution to the bridge deck deterioration problem. By providing an impermeable barrier they prevent the intrusion of chlorides and moisture into the concrete deck. In New York, membranes are considered for use only in rehabilitation work. For new construction, or complete deck replacement, the current practice is to construct the structural deck and wearing surface monolithically, using epoxy coated reinforcing bars in the top mat.

Purpose and Scope

This study is being conducted in conjunction with National Experimental and Evaluation Program (NEEP) No. 12, Bridge Deck Protective Systems. The purpose of this program is to evaluate membrane waterproofing systems for use in concrete bridge deck maintenance and repair work. The membranes in this evaluation are preformed sheets or liquid systems, that are placed as a waterproof barrier between an existing concrete deck and a bituminous concrete overlay wearing surface.

This report describes the performance of five membrane systems after one year in service. Three of the membrane systems are preformed sheets that have been designated as non-experimental by the Federal Highway Administration (Bituthene, Royston and Protecto-Wrap). The other two membranes are liquid systems. The first is an experimental, low temperature PVC polymer. This system is marketed on the East coast by POSH Chemical, Inc. as NEA-4000LT and is similar to Superior Products Co.'s Superseal-4000LT. The second liquid is a non-proprietary two-coat bituminous epoxy membrane system. The materials specifications for each membrane type are summarized in Appendix A.

Previous Work

A detailed description of the test areas; observations made during installation; specification requirements, etc. are included in the first interim report on this project: Technical Report 32, Membrane Applications in New York, dated April, 1977.

In review, each of the five membrane systems was applied to a test structure and overlayed with a 2½ inch thick bituminous concrete wearing course. No problems were encountered during the installation or paving of any of the waterproofing systems. To protect against damage from puncturing, the preformed sheet systems were paved with a bituminous concrete mix having a maximum aggregate size of 3/8 inch. No other protective courses were used to protect the preformed membranes. Based on electrical resistance measurements that were taken on the surface of the completed overlay, all of the membranes, except for the bituminous epoxy system, were performing satisfactorily at the time of installation. On the basis of the resistance test, the initial impermeability of the epoxy membrane was questionable.

Table 1 (Note 1) is a summary of the data that was collected at the time of the membrane installations. The results are given in three categories: data collected on the concrete structural deck before the membrane was applied; data collected on the surface of the membrane before the overlay was paved; and data collected after the work was completed with the bituminous concrete overlay in place. A last entry gives the contractor's installation cost (materials, labor, etc.) for each of the five systems.

Note 1. Table 1 is reprinted from the first interim report (T.R. No. 32). In the initial report several typographical errors were included in this Table. These errors have been corrected in this printing.

TABLE 1 SUMMARY OF MEMBRANE WATERPROOFING INSTALLATION DATA

	HEAVY DUTY BITUTHENE		PROTECTO-WRAP M-400A	ROYSTON MEMB. NO. 10	NEA-4000 LT		BITUMINOUS EPOXY (2 COATS)		
	SPAN 1 NB	SPAN 2 NB			SPAN 2 SB	SPAN 5 SB	SPAN A	SPAN B	SPAN C
1. CONCRETE STRUCTURAL DECK									
Type of Deck	Old (Existing)		New	New	Old (Existing)		Old (Existing)		
Chloride Content (lbs. Cl^-/c.y.)									
1" depth	4.8	3.6	0.3	0.3	3.2	1.8	3.2	3.6	2.9
2" depth	1.0	2.2	0.3	0.6	1.2	0.4	1.7	2.2	1.8
3" depth	**	2.5	0.4	0.6	0.5	0.3	1.2	1.3	1.2
Corrosion Potential, Average (CSE)	0.27v.	0.14v.	0.26v.	0.28v.	0.23v.	0.23v.	0.25v.	0.19v.	0.24v.
Electrical Resistance (kil-ohms-s.f.)	2-3	2-3	2-3	2-3	3-6	3-6	2-4	2-4	2-4
2. MEMBRANE WATERPROOFING									
Application Problems	none	none	none	none	none	none	none	none	*
Electrical Resistance (before overlay)									
Total Number of Measurements:	35	55	70	57	36	31	**	**	*
Less than 100 kil-ohm-s.f.	0	0	0	0	0	0			
100-500 kil-ohm-s.f.	0	0	0	0	2	0			
Greater than 500 kil-ohm-s.f.	35	55	70	57	34	31			
3. BITUMINOUS OVERLAY									
Paving Problems	none	none	none	none	none	none	none	none	none
Electrical Resistance (after overlay)									
Total Number of Measurements:	45	61	80	60	62	65	20	20	20
Less than 100 kil-ohm-s.f.	0	1	0	1	1	0	8	11	10
100-500 kil-ohm-s.f.	1	5	1	4	1	2	6	6	6
Greater than 500 kil-ohm-s.f.	44	55	79	55	60	63	6	3	4
4. INSTALLATION COST ($/s.v.)- not including bituminous overlay	$4.50	$4.50	$4.50	$4.50	$4.50	$4.50	$23.85	$23.85	$0.00*

* No membrane treatment
** Data not available

II METHODS OF EVALUATION

The performance of membrane waterproofing systems is being determined on the basis of annual evaluations. In each survey the observations and measurements listed below are recorded and interpreted as follows:

1. Visual Observations: to locate cracks, areas of water seepage and other types of visible distress.

2. Electrical Resistance: electrical resistance measurements will be taken on a five-foot by five-foot coordinate grid to test for the impermeability (waterproofing quality) of the membrane system. The method of test consists of measuring the electrical resistance between an electrode placed on the surface of the deck and the top mat of reinforcing steel in the deck. Testing on waterproofing membranes has resulted in the following interpretation of electrical resistance measurement values:

Electrical Resistance Value	Membrane Performance
Greater than 500 kil-ohm-s.f.	acceptable
Less than 100 kil-ohm-s.f.	unacceptable
Between 100-500 kil-ohm-s.f.	inconclusive

   It should be noted that when measurements are made through a bituminous wearing surface, an error may be introduced due to the electrical resistance of the wearing surface. If such an error is introduced, it will be in the direction of indicating a higher resistance value, and therefore better membrane performance than has actually occurred. The magnitude of this error has been estimated at 0.9% at 100 kil-ohm-s.f.; 4.5% at 500 kil-ohm-s.f.; and 58.0% at 6400 kil-ohm-s.f. No correction for such an error, if present, will be made in these initial reports.(1)

3. Corrosion Potential: corrosion potential measurements will be taken on a five-foot by five-foot coordinate grid, using a copper-copper sulphate half-cell reference electrode. This test method can be used on exposed concrete slabs to define areas of reinforcing bar corrosion activity.

(1) Reference:
Chamberlin, W.P., Irwin, R.J., and Amsler, D.E.
Waterproofing Membranes for Bridge Deck Rehabilitation. Research Report 52, Engineering Research and Development Bureau, New York State Department of Transportation, May, 1977.

Research on concrete slabs with uncoated steel reinforcement has shown that for half-cell values (CSE) of less than 0.20v., active corrosion of the steel bars is not occurring; and that for values above 0.35v., active corrosion is occurring. The range of values between 0.2v. and 0.35v. represents an area where corrosion activity is undefined.

In conducting the corrosion potential test on bridge decks with waterproofing membranes, we have noted that a high electrical resistance measurement (greater than 500 kil-ohms-s.f.) is usually associated with a low corrosion potential (less than 0.20v.). This appears to be a logical result when it is considered that the corrosion potential measurement is dependent on "solution contact", between the end of the $Cu\text{-}CuSO_4$ half-cell on the surface, and the reinforcing bars in the deck. Without this wetted connection a circuit is not completed, and the corrosion potential cannot be recorded. When the test is taken on an impervious membrane, the wetted connection is interrupted, which results in an incomplete circuit and low corrosion potential value. Measurements on our test structures show that electrical resistance values approaching infinity, are usually associated with a corrosion potential near 0.0v. If the membrane is slightly damaged, e.g. - has a few holes, the circuit is partially established but the resistance of the membrane remains high enough to prevent an accurate potential measurement. The result is that the reading remains low. Only when the membrane becomes damaged to the extent that it easily allows the passage of moisture, can a good circuit be established and an accurate corrosion potential value recorded.

On the basis of this, the results of corrosion potential tests will be interpreted as follows:

a. A corrosion potential of less than 0.20v. is indicative of acceptable membrane performance; but not necessarily an indication of reinforcing bar corrosion activity.

b. A corrosion potential of greater than 0.35v. is indicative of unacceptable membrane performance and a probable indication that active corrosion of the reinforcing steel is occurring.

c. The range of corrosion potential values between 0.20v. to 0.35v. is undefined, in regard to membrane performance and corrosion activity.

4. Chloride Analysis, Cores, Etc.

Prior to the membrane installation, chloride samples were taken from the concrete structural decks to establish a base level for chloride contamination (Table 1). Research has shown that a chloride content of from 1 to 1.3 pounds of free chloride ion per cubic yard of concrete is sufficient to promote active corrosion of uncoated reinforcing bars. In the future, and when it is warranted by the other methods of evaluation, cores will be taken for visual examination to verify membrane performance, and for chloride sampling for comparison with the base level contents.

III OBSERVATIONS AND RESULTS

In 1977 each of the membrane systems was evaluated. This survey was performed at a time when each of the test structures had been in service for approximately one year. In this survey each test installation was evaluated visually, and by electrical resistance and corrosion potential measurement. A brief discussion of each membrane system is given below.

The results of the electrical resistance and corrosion potential surveys are summarized in Table 2. The resistance data is only given as a percentile of measurement values that were recorded in a performance interval. A statistical analysis of the electrical resistance measurements is not practical because of the large difference in magnitude between data values, e.g. high measurements near infinity, when included with lower values of less than 100 kil-ohms, combine to provide a meaningless result. In addition to Table 2, the results of the resistance and potential tests are shown in the contour maps, Figures 1 through 8. The contour maps are plotted to visually display areas of electrical resistance in the intervals of less than 100; 100 to 500; and greater than 500 kil-ohms-s.f. Corrosion potential data are plotted in the intervals of less than 0.20v.; .20 to .35v.; and greater than 0.35v.

Heavy Duty Bituthene

Heavy Duty Bituthene waterproofing membrane is being evaluated on two spans (Spans 1NB and 2NB) of a structure located near Corning, N.Y. No visual defects were noted on either of the test spans. Electrical resistance testing indicates that the majority of the membrane area is satisfactory. From Table 2, 83% of the values on Span 1 and 82% of the measurements on Span 2 exceeded 500 kil-ohm-s.f. Corrosion potential testing also indicates satisfactory performance; with the mean potentials being 0.16v. and 0.10v. on Spans 1 and 2, respectively.

Figures 1 thru 4 are the contour plots of the electrical resistance and corrosion potential surveys. From Figures 1 and 3, it can be seen that the majority of deck areas showed an electrical resistance value in excess of 500 kil-ohm-s.f. In Figures 2 and 4, the corrosion potentials are plotted. Span 1, shows that the greatest number of data points were recorded as less than 0.20v. (70 measurements); however, 44 values were measured in the undefined performance interval (0.20 to 0.35v.) and 9 data points exceeded 0.35v. On Span 2 (Figure 4), the corrosion potentials are seen to be more uniform; 156 measurements are less than 0.20v., 32 are between 0.2-0.35v., and 10 values exceeded 0.35v.

In general, all the methods of evaluation, indicate the Heavy Duty Bituthene is performing satisfactorily after 1 year's service.

TABLE 2 - ELECTRICAL RESISTANCE AND CORROSION POTENTIAL TESTING

Membrane System	Survey Year	Years In-Service	Electrical Resistance				Corrosion Potential							
				Percentiles								Percentiles		
			No. Meas.(n)	>500k	500 to 100k	<100k	No. Meas.(n)	Mean (volts)	Std. Dev.	Min. (volts)	Max. (volts)	<.20v.	.20-.35v.	>.35v.
HEAVY DUTY BITUTHENE														
Span 1	1976	0	45	98	2	0	*	*	*	*	*	*	*	*
	1977	1	125	83	6	11	123	0.16	0.13	0.00	0.44	57	36	7
Span 2	1976	0	61	90	8	2	*	*	*	*	*	*	*	*
	1977	1	198	82	11	7	198	0.10	0.12	0.00	0.48	79	16	5
PROTECTO-WRAP M-400A														
	1976	0	80	99	1	0	*	*	*	*	*	*	*	*
	1977	1	263	92	4	4	263	0.09	0.10	0.00	0.41	77	22	1
ROYSTON-BRIDGE MEMB. NO. 10	1976	0	60	92	7	1	*	*	*	*	*	*	*	*
	1977	1	180	76	16	8	180	0.18	0.11	0.00	0.39	45	52	3
NEA-4000 LT														
Span 2	1976	0	62	97	2	1	*	*	*	*	*	*	*	*
	1977	1	70	86	8	6	70	0.12	0.15	0.00	0.68	70	24	6
Span 5	1976	0	65	97	3	0	*	*	*	*	*	*	*	*
	1977	1	70	80	4	16	70	0.14	0.18	0.00	0.71	63	27	10
BITUMINOUS EPOXY (2-COATS)														
Span A	1976	0	20	30	30	40	*	*	*	*	*	*	*	*
	1977	1	153	3	11	86	153	0.28	0.07	0.12	0.48	8	79	13
Span B	1976	0	20	15	30	55	*	*	*	*	*	*	*	*
	1977	1	207	0	1	99	207	0.22	0.07	0.08	0.44	48	48	4
**Span C	1976	0	20	20	30	50	*	*	*	*	*	*	*	*
	1977	1	207	2	4	94	207	0.32	0.09	0.02	0.62	7	60	33

* Corrosion potential testing on paved membrane was not performed in 1976 survey
** No waterproofing membrane treatment

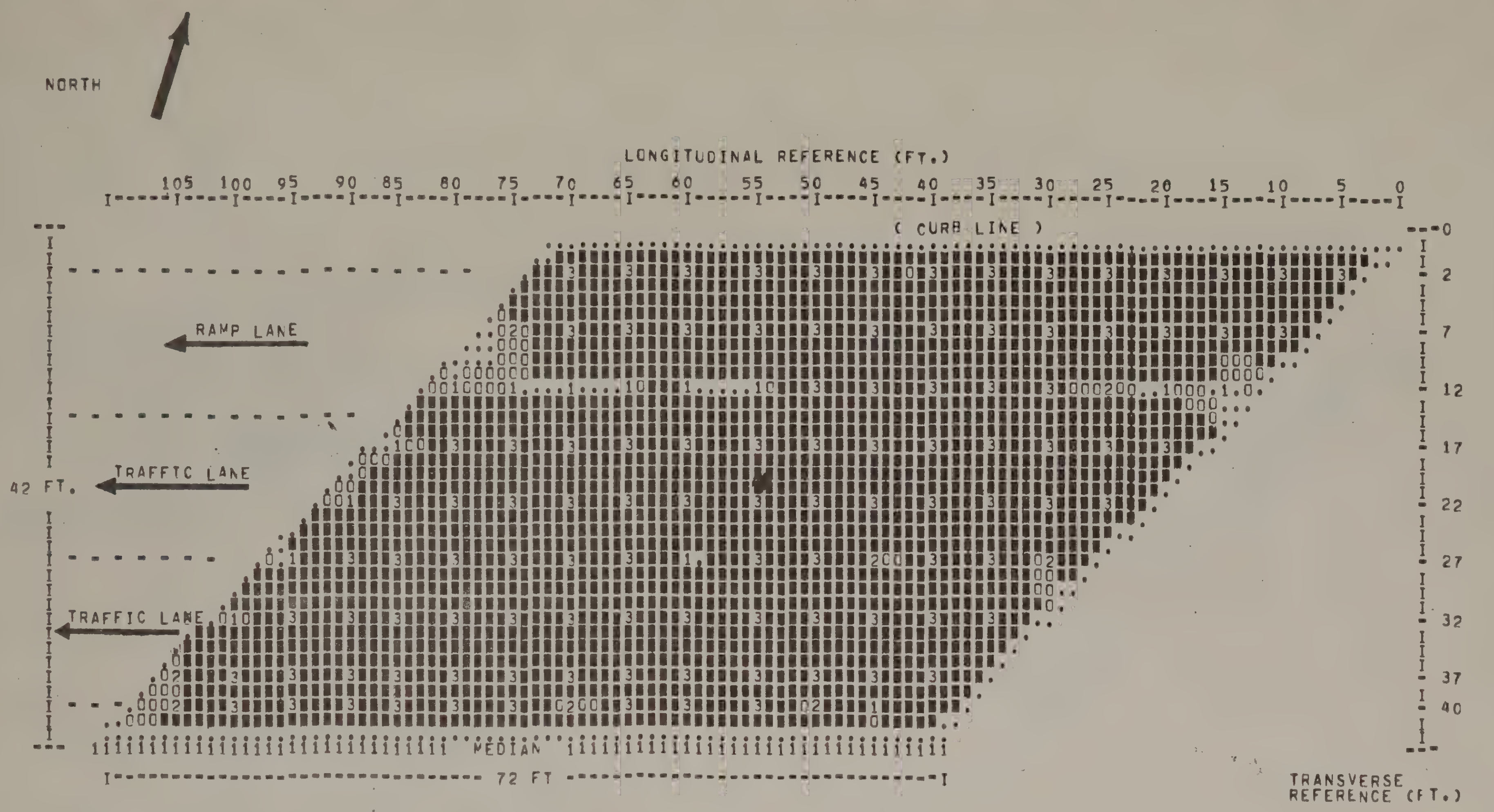

Figure 1 - Electrical Resistance
1977 Survey (In-Service - 1 year)

```
SYMAP

DATA VALUE EXTREMES ARE        10.00     9999.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00     100.00    501.00
  MAXIMUM     100.00     501.00  10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              1.00       4.01      94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
          ==============================
           .........  OOOOOOOOO  ████████
           .........  OOOOOOOOO  ████████
  SYMBOLS  ....1....  OOOO2OOOO  ████3███
           .........  OOOOOOOOO  ████████
           .........  OOOOOOOOO  ████████
          ==============================
  FREQ.         14         8        103
   2.1 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.2 MINUTES TOTAL PROCESSOR TIME
   0.9 MINUTES TOTAL IO TIME
TIME OF DAY =  1/26
```

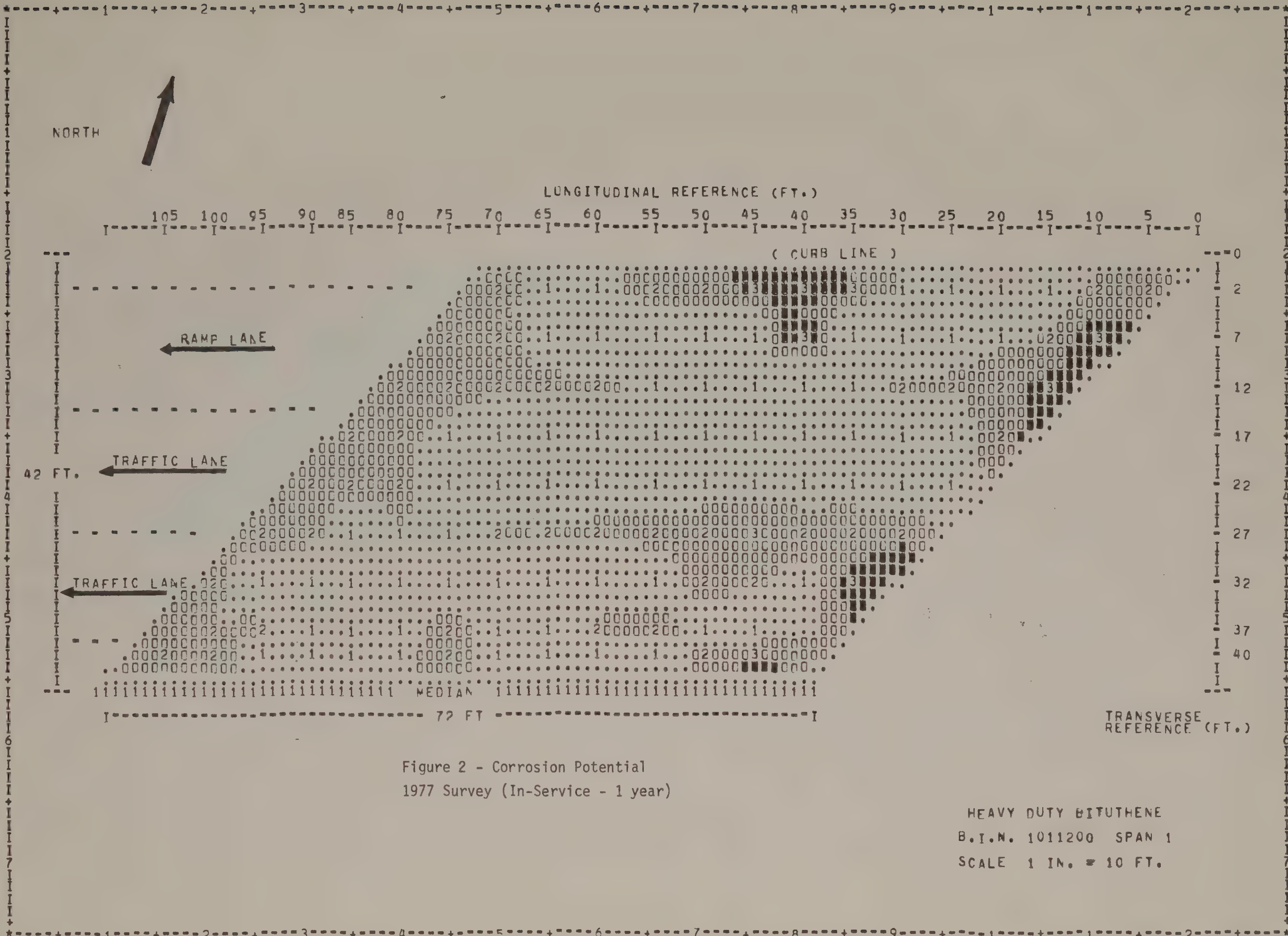

Figure 2 - Corrosion Potential
1977 Survey (In-Service - 1 year)

```
SYMAP



DATA VALUE EXTREMES ARE          0.00          0.44


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1          2          3
          ===============================
           .........  OOOOOOOOO  █████████
           .........  OOOOOOOOO  █████████
  SYMBOLS  ....1....  OOOO2OOOO  ████3████
           .........  OOOOOOOOO  █████████
           .........  OOOOOOOOO  █████████
          ===============================
  FREQ.        70         44          9
   2.5 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.2 MINUTES TOTAL PROCESSOR TIME
   1.1 MINUTES TOTAL IO TIME
TIME OF DAY = 10/36
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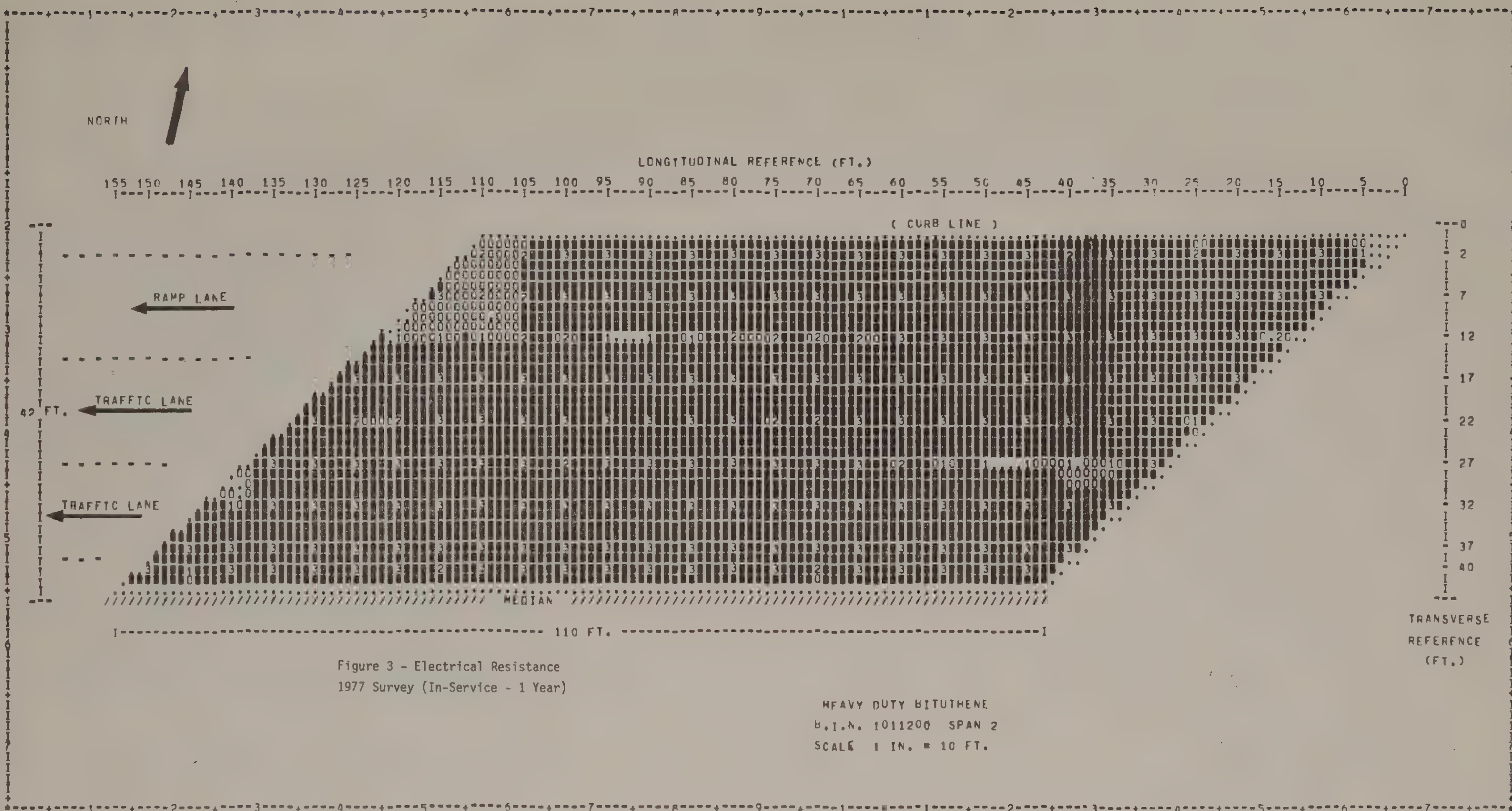

Figure 3 - Electrical Resistance
1977 Survey (In-Service - 1 Year)

HEAVY DUTY BITUTHENE
B.I.N. 1011200 SPAN 2
SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          10.00       9999.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM> INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00     100.00     501.00
  MAXIMUM     100.00     501.00   10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                1.00       4.01      94.99


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3
          ===============================
           .........  CCCCCCCCC ■■■■■■■■■
           .........  CCCCCCCCC ■■■■■■■■■
  SYMBOLS  ....1....  CCCC2CCCC ■■■■3■■■■
           .........  CCCCCCCCC ■■■■■■■■■
           .........  CCCCCCCCC ■■■■■■■■■
          ===============================
  FREQ.          15         21        182
   3.1 MINUTES ELAPSED TIME FOR HISTOGRAM
   3.3 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME
TIME OF DAY =  3/37
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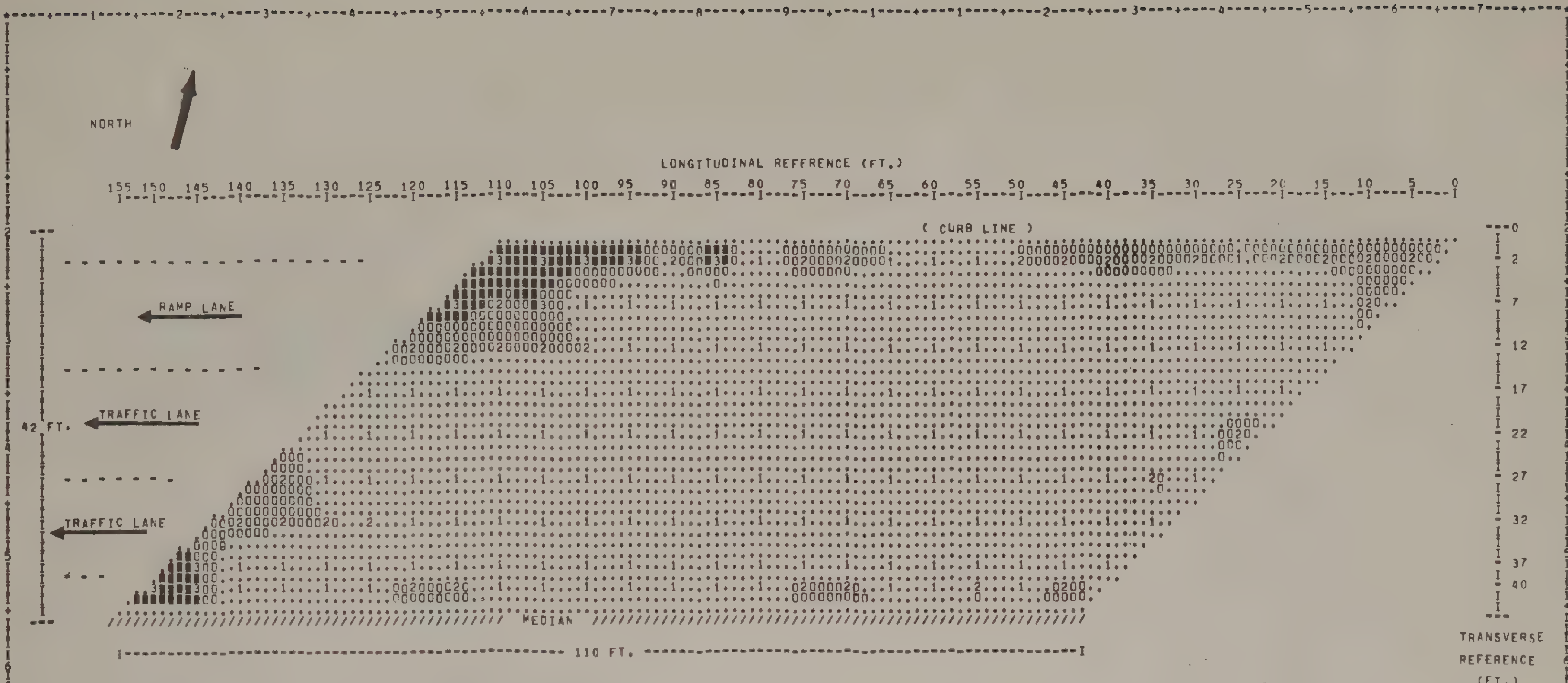

Figure 4 - Corrosion Potential
1977 Survey (In Service - 1 year)

HEAVY DUTY BITUTHENE
B.I.N. 1011208 SPAN 2
SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          0.00         0.48


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
          ===============================
           .........  OOOOOOOOO █████████
           .........  OOOOOOOOO █████████
  SYMBOLS  ....1....  OOOO2OOOO ████3████
           .........  OOOOOOOOO █████████
           .........  OOOOOOOOO █████████
          ===============================
  FREQ.        156        32         10
   3.5 MINUTES ELAPSED TIME FOR HISTOGRAM
   3.3 MINUTES TOTAL PROCESSOR TIME
   1.3 MINUTES TOTAL IO TIME
TIME OF DAY =  3/33
```

Protecto-Wrap M400A

Protecto-Wrap waterproofing membrane is being evaluated on one test structure near Waverly, N.Y. In 1977, 92% of the electrical resistance measurements were recorded as greater than 500 kil-ohm-s.f., and the mean of the corrosion potential tests was 0.09v. No visual defects were visible. Figures 5 and 6 are the contour plots of the resistance and potential surveys. After one year of service it appears that the Protecto-Wrap M-400A waterproofing membrane is performing satisfactorily.

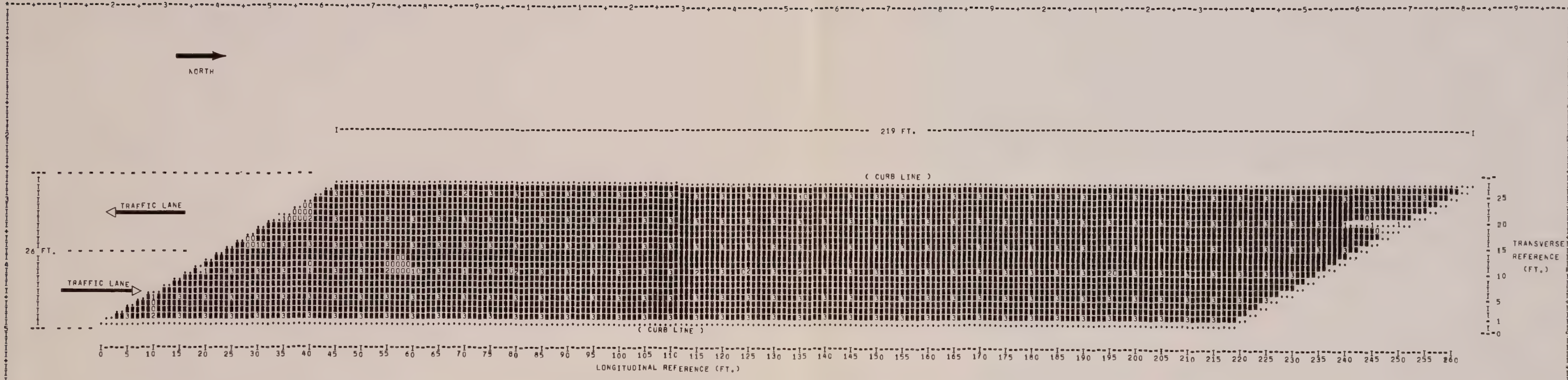

Figure 5 - Electrical Resistance
1977 Survey (In-Service: 1 year)

```
DATA VALUE EXTREMES ARE          10.00      9999.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00     100.00    501.00
  MAXIMUM     100.00     501.00  10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               1.00       4.01      94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
            ==============================
             .........  CCCCCCCCC  █████████
             .........  CCCCCCCCC  █████████
  SYMBOLS    ....1....  CCCC2CCCC  ████3████
             .........  CCCCCCCCC  █████████
             .........  CCCCCCCCC  █████████
            ==============================
  FREQ.         11        10        242
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   4.4 MINUTES TOTAL PROCESSOR TIME
   1.2 MINUTES TOTAL IO TIME
TIME OF DAY = 11/51
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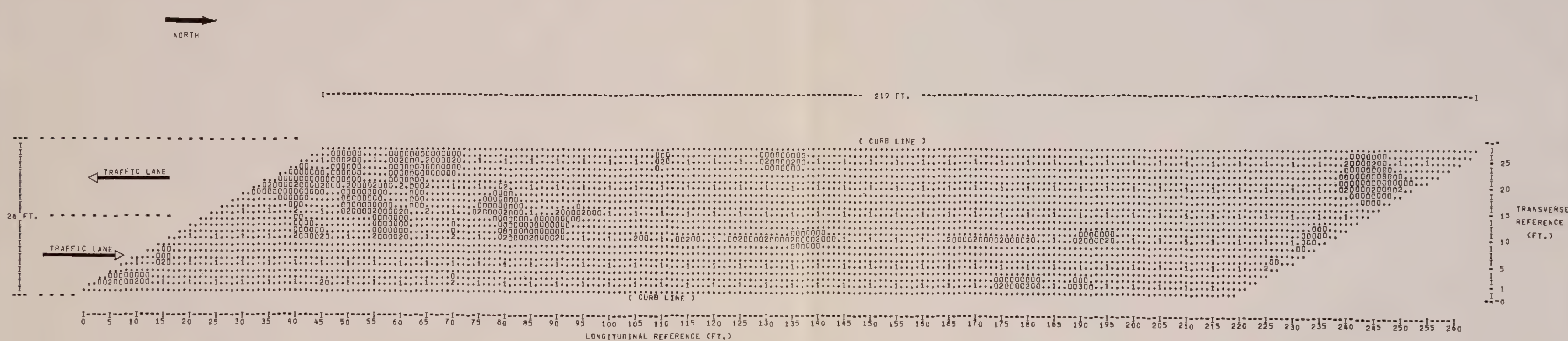

Figure 6 - Corrosion Potential
1977 Survey (In-Service: 1 Year)

PROTECTO WRAP M-400 A
B.I.N. 1023170
SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          0.00         0.41


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               25.00      20.00      55.00


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
            ===============================
             .........  000000000 █████████
             .........  000000000 █████████
  SYMBOLS    ....1....  000020000 ████3████
             .........  000000000 █████████
             .........  000000000 █████████
            ===============================
  FREQ.        204        57         2
   3.9 MINUTES ELAPSED TIME FOR HISTOGRAM
   4.2 MINUTES TOTAL PROCESSOR TIME
   1.2 MINUTES TOTAL IO TIME
TIME OF DAY = 12/ 9
```

Royston Bridge Membrane No. 10

Royston waterproofing membrane is also being tested on one bridge near Waverly, N.Y. Generally this system is considered satisfactory, but based on the 1977 survey its overall performance is judged to be less than the other two preformed sheets. Visual observations showed four defects on the deck surface; all in the form of 6-10 inch diameter circular cracking patterns where the bituminous overlay was lifted, and "spongy." When pressure was applied, water could be pumped from these soft spots. Electrical resistance tests show that 76% of the measured values were greater than 500 kil-ohms-s.f. and the average corrosion potential was recorded at 0.18v. Figures 7 and 8 are the electrical resistance and corrosion potential contours for the Royston membrane. In Figure 7, the location of the visual defects correspond with the lower resistance measurements at the North end of the deck.

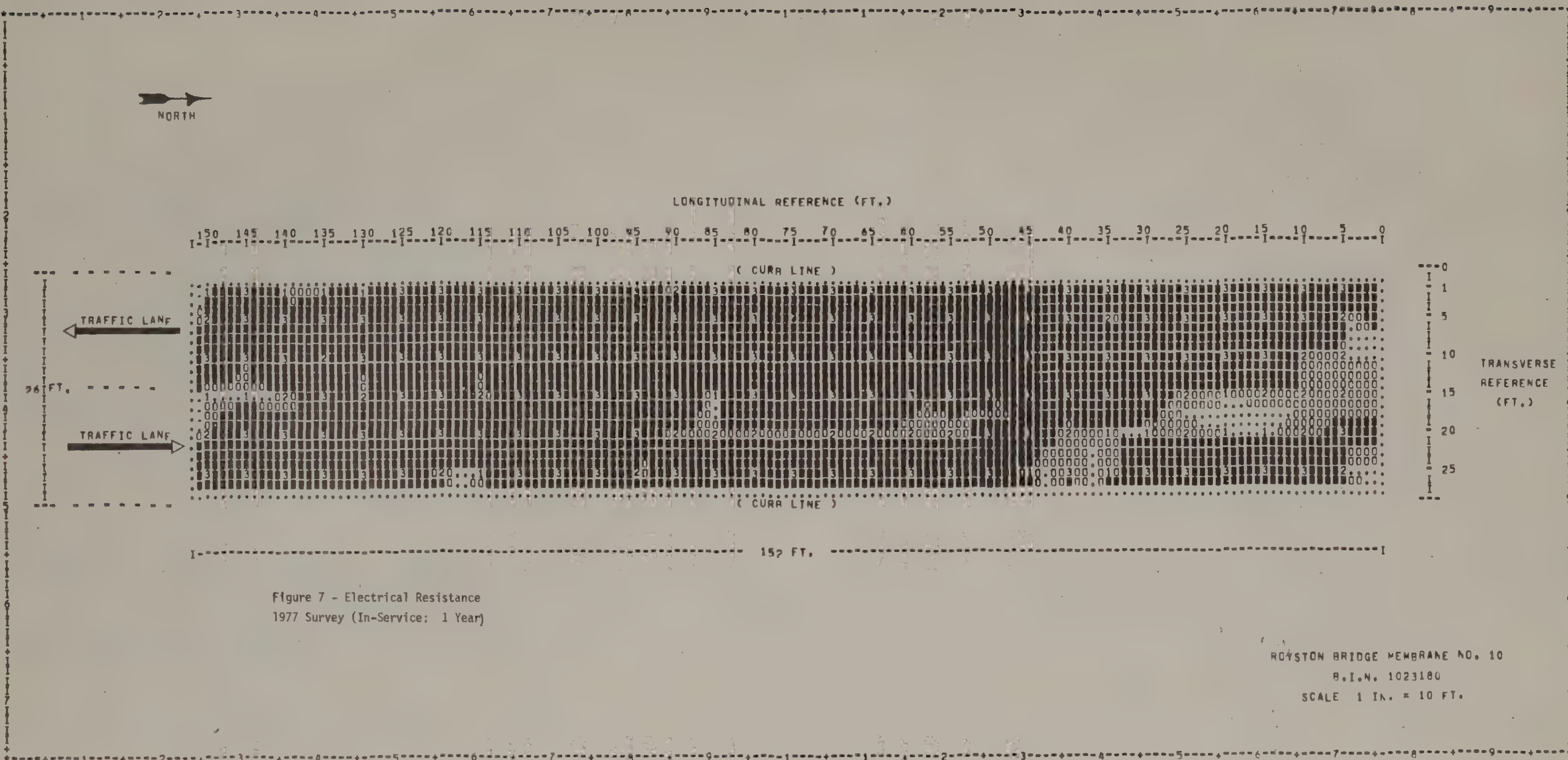

Figure 7 - Electrical Resistance
1977 Survey (In-Service; 1 Year)

```
DATA VALUE EXTREMES ARE         10.00     9999.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.00     100.00     501.00
  MAXIMUM    100.00     501.00   10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               1.00       4.01      94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
          ===============================
           ......... OOOOOOOOO █████████
           ......... OOOOOOOOO █████████
  SYMBOLS  ....1.... OOOO2OOOO ████3████
           ......... OOOOOOOOO █████████
           ......... OOOOOOOOO █████████
          ===============================
  FREQ.         15        29       136
   2.7 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.9 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME
TIME OF DAY = 11/54
```

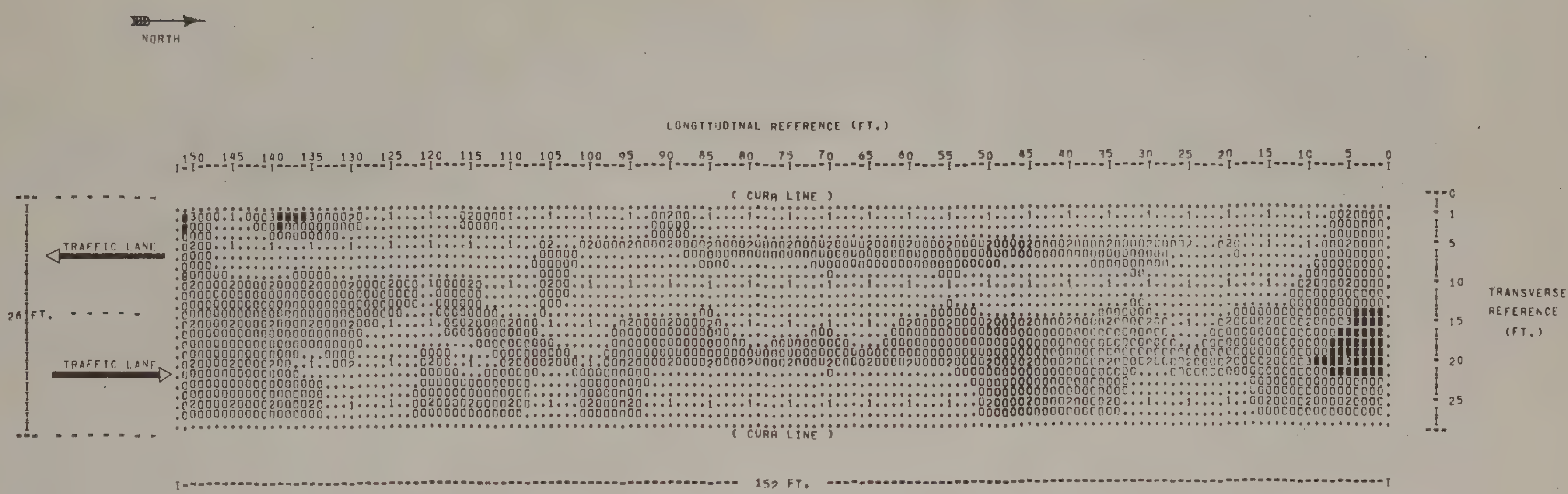

Figure 8 - Corrosion Potential
1977 Survey (In-Service: 1 Year)

ROYSTON BRIDGE MEMBRANE NO. 10
B.I.N. 1023180
SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          0.00          0.39


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (≥MAXIMUM> INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00        0.20        0.36
  MAXIMUM       0.20        0.36        0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              25.00       20.00       55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
           ================================
            ......... 000000000 █████████
            ......... 000000000 █████████
  SYMBOLS   ....1.... 000020000 ████3████
            ......... 000000000 █████████
            ......... 000000000 █████████
           ================================
  FREQ.         80         94          6
   2.8 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.8 MINUTES TOTAL PROCESSOR TIME
   1.1 MINUTES TOTAL IO TIME

TIME OF DAY =  3/59
```

NEA-4000 LT (Low Temperature)

The liquid NEA-4000 LT membrane is being evaluated on two spans (Span 2 SB and Span 5 SB) of a test structure near Corning, N.Y. No visual defects were noted on Span 2; nor on Span 5, except that a small (2'x4') area of the pavement had "shoved" next to the curb line at the North end of the steel floor grating. After one year of service 86% of the electrical resistance tests on Span 2 and 80% of the values on Span 5 were recorded as greater than 500 kil-ohm-s.f. Most of the lower resistances on Spans 2 and 5 (Figures 9 and 11) were measured at the pavement centerline. Work on this bridge was progressed in two stages to maintain traffic and the center of the pavement represents a construction joint. It is possible that the membrane was damaged by construction activities at this location.

The average corrosion potential of the NEA-4000 LT on Span 2 was 0.12v. and on Span 5, 0.14v. Corrosion potential contours are plotted in Figures 10 and 12.

Based on the information from the 1977 survey, it appears that the NEA-4000 LT liquid membrane system is performing satisfactorily after one year in service.

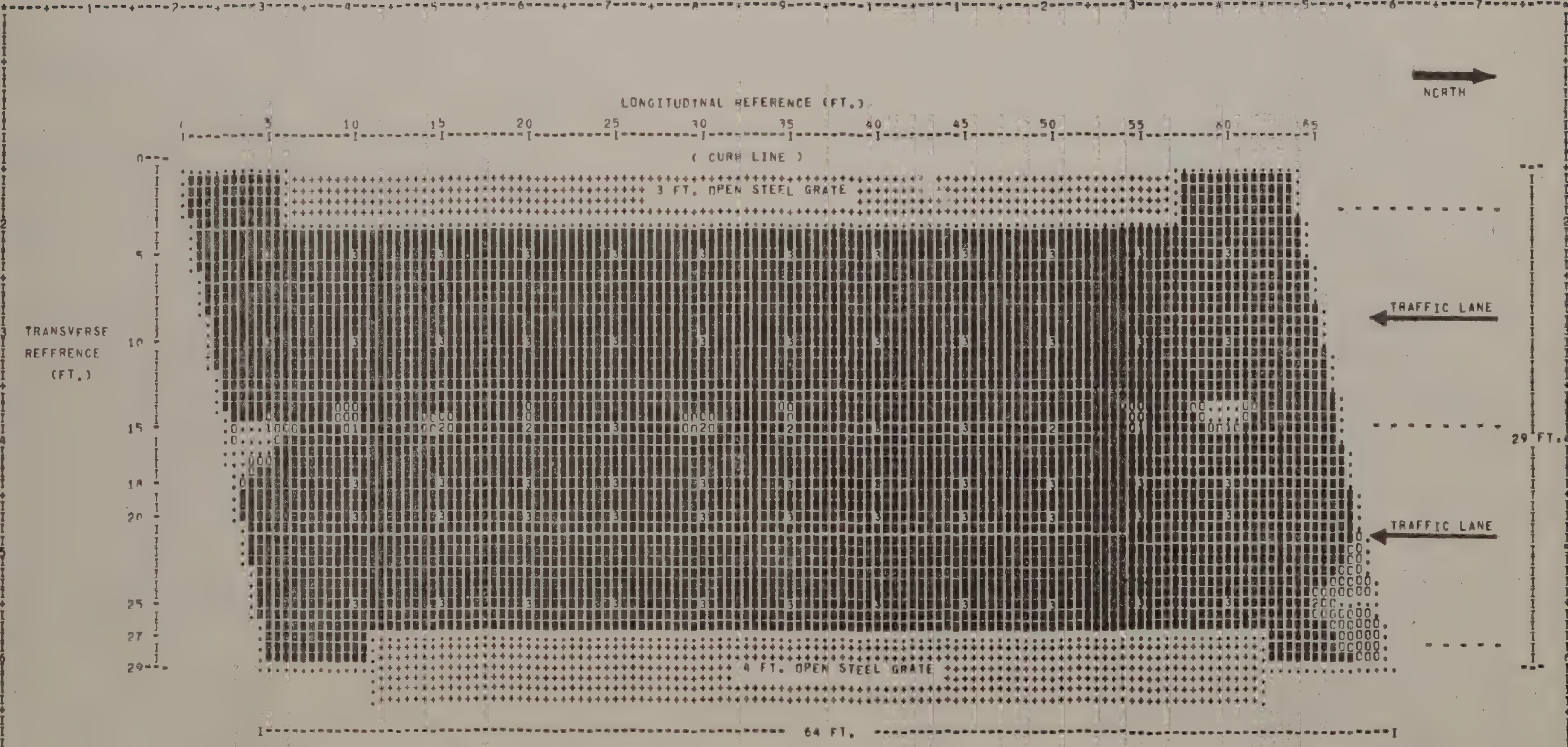

Figure 9 - Electrical Resistance
1977 Survey (In-Service: 1 Year)

```
DATA VALUE EXTREMES ARE          9.00      9999.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM> INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00     100.00     501.00
  MAXIMUM     100.00     501.00   10000.00


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                1.00       4.01      94.99


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL             1         2         3
            ===============================
             .........  CCCCCCCCC █████████
             .........  CCCCCCCCC █████████
  SYMBOLS    ....1....  CCCC2CCCC ████3████
             .........  CCCCCCCCC █████████
             .........  CCCCCCCCC █████████
            ===============================
  FREQ.             4         6        60
   3.2 MINUTES ELAPSED TIME FOR HISTOGRAM
   3.1 MINUTES TOTAL PROCESSOR TIME
   0.9 MINUTES TOTAL IO TIME
TIME OF DAY =  3/41
```

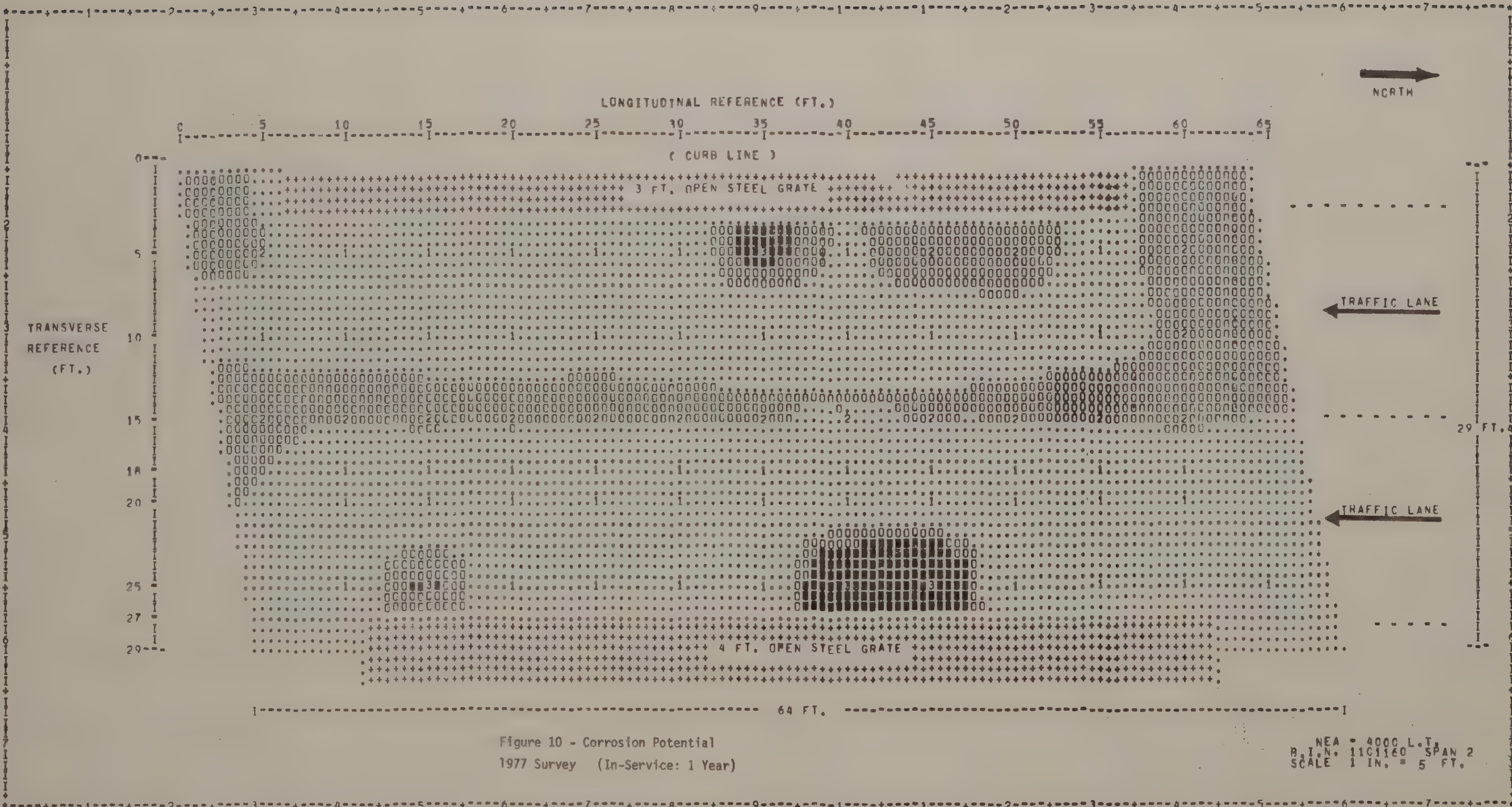

Figure 10 - Corrosion Potential
1977 Survey (In-Service: 1 Year)

```
DATA VALUE EXTREMES ARE          0.00         0.68


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.00       0.20       0.36
  MAXIMUM      0.20       0.36       0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
          ===============================
           .........  COCCCOOOC █████████
           .........  COCCCOOOC █████████
  SYMBOLS  ....1....  COCC2OOOC ████3████
           .........  COCCCOOOC █████████
           .........  COCCCOOOC █████████
          ===============================
  FREQ.         49         17          4
   3.1 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.9 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME
TIME OF DAY = 10/45
```

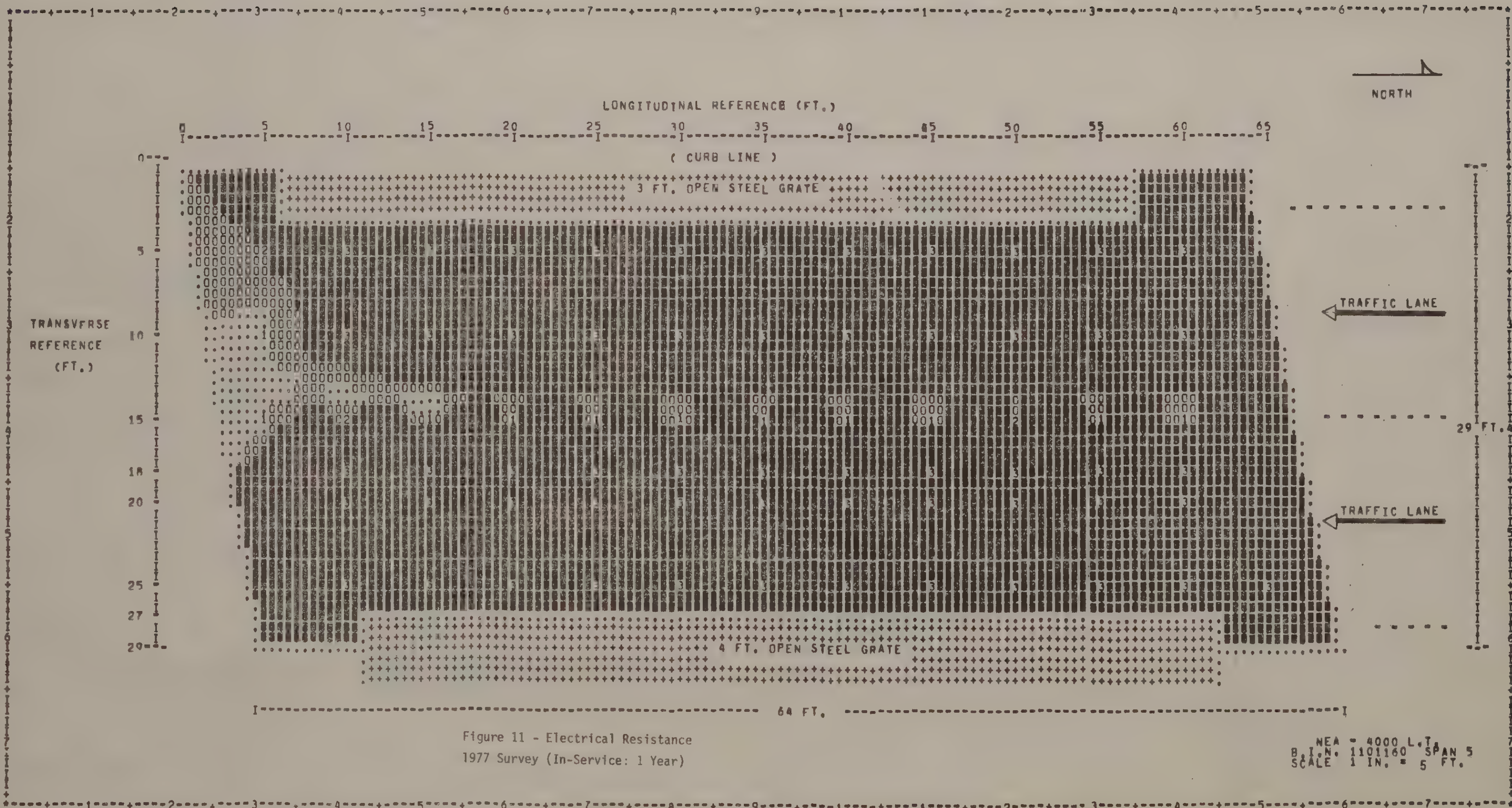

Figure 11 - Electrical Resistance
1977 Survey (In-Service: 1 Year)

```
DATA VALUE EXTREMES ARE          14.00       9999.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.00     100.00      501.00
  MAXIMUM      100.00     501.00    10000.00


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                1.00       4.01       94.99


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
            ===============================
             .........  000000000 █████████
             .........  000000000 █████████
  SYMBOLS    ....1....  000020000 ████3████
             .........  000000000 █████████
             .........  000000000 █████████
            ===============================
  FREQ.         11         3        56
   3.2 MINUTES ELAPSED TIME FOR HISTOGRAM
   3.1 MINUTES TOTAL PROCESSOR TIME
   0.9 MINUTES TOTAL IO TIME

TIME OF DAY =  3/33
```

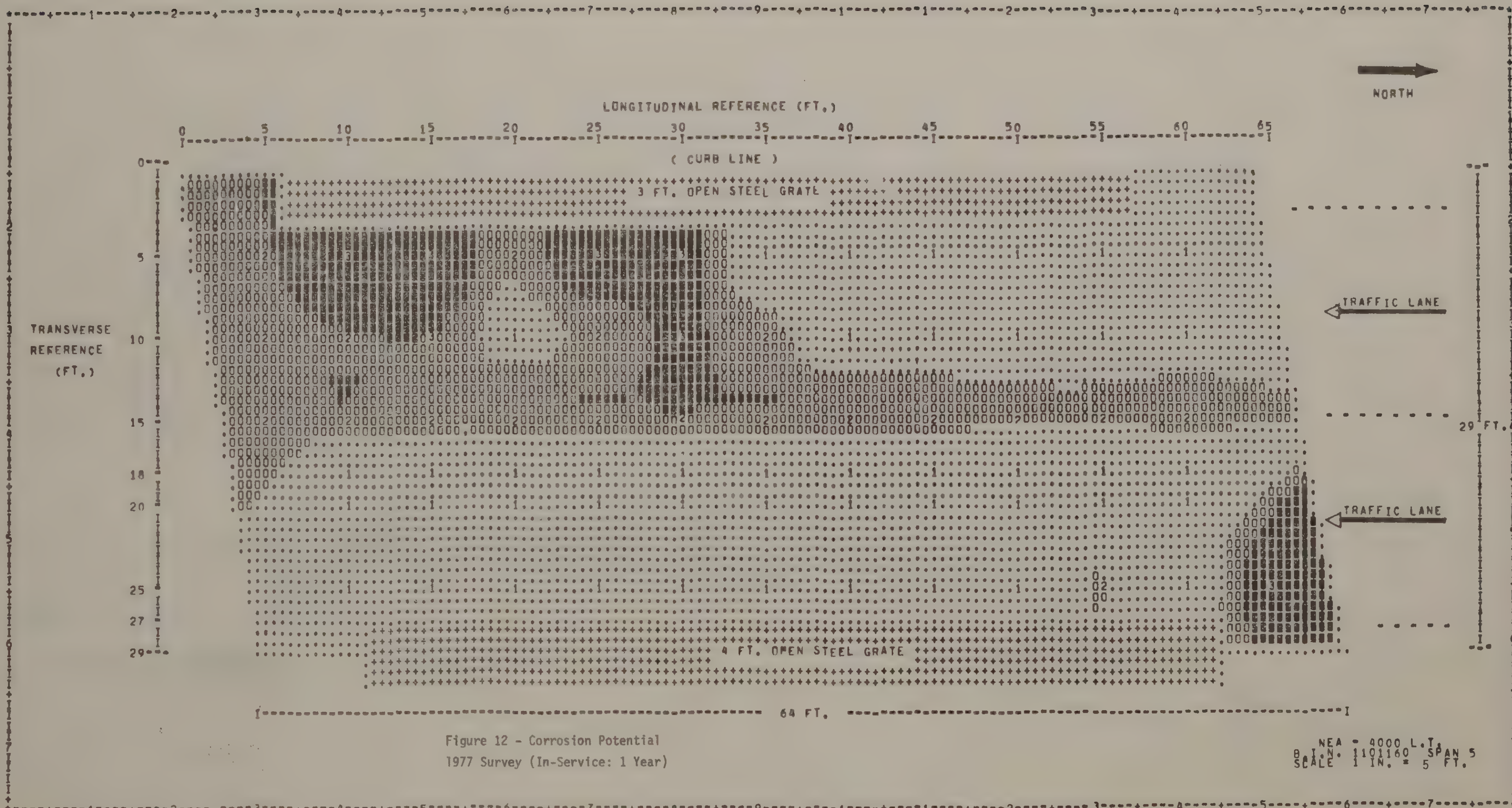

Figure 12 - Corrosion Potential
1977 Survey (In-Service: 1 Year)

```
DATA VALUE EXTREMES ARE          0.00          0.71


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3
            ===============================
             .........  000000000  █████████
             .........  000000000  █████████
  SYMBOLS    ....1....  000020000  ████3████
             .........  000000000  █████████
             .........  000000000  █████████
            ===============================
  FREQ.           44         19          7
   3.3 MINUTES ELAPSED TIME FOR HISTOGRAM
   3.1 MINUTES TOTAL PROCESSOR TIME
   1.1 MINUTES TOTAL IO TIME
TIME OF DAY =  3/29
```

Bituminous Epoxy Membrane (Two Coat Application)

As noted in the first interim report, based on electrical resistance testing the bituminous epoxy membrane appeared to be ineffective immediately after installation. The 1977 survey indicates the same degree of performance.

The membrane is being evaluated on two spans of a three span structure, located between the Cities of Tonawanda and N. Tonawanda, N.Y. Spans A and B have been waterproofed with the epoxy membrane; Span C is on a 5-1/2% grade and has no waterproofing treatment. Span C is included in this evaluation as a control section for comparison purposes.

No visual defects were evident on any of the three spans. Electrical resistance tests on Spans A and B show that only 3% of the measurements on Span A and no (0%) values on Span B exceed the 500 kil-ohms-s.f. acceptable limit. By contrast, 86% and 99% of the values on these spans are below 100 kil-ohms-s.f., which indicates unacceptable membrane performance. Electrical resistance tests on Span C show 2% of the values as greater than 500 kil-ohms, and 94% as less than 100 kil-ohms-s.f. These results are comparable to those on Spans A and B that have the epoxy waterproofing treatment.

The average corrosion potential on Spans A and B was recorded as 0.28v. and 0.22v., respectively; Span C showed 0.32v. These values represent undefinable membrane performance.

The electrical resistance and corrosion potential contours for the spans with the bituminous epoxy membrane system and for the untreated Span C are shown in Figures 13 thru 18.

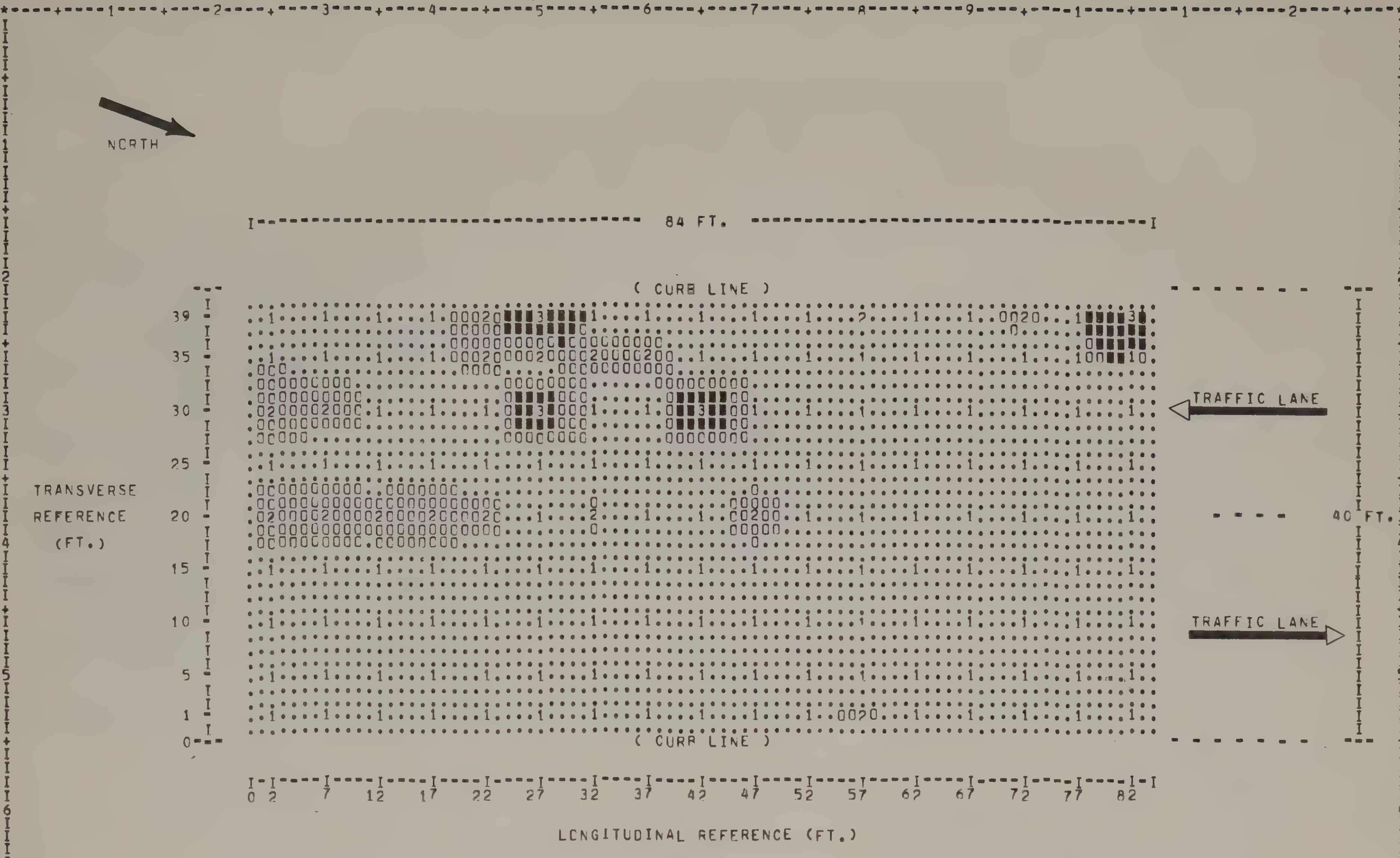

Figure 13 - Electrical Resistance

1977 Survey (In-Service: 1 Year)

TWO-COAT BITUMINOUS EPOXY MEMBRANE

B.I.N. 4453030 SPAN A

SCALE 1 IN. = 10 FT.

```
SYMAP


DATA VALUE EXTREMES ARE          3.0C      7000.CC


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.CC      10C.00     501.00
  MAXIMUM      10C.0C      501.0C   1000C.0C

PERCENTAGE OF TOTAL ABSCLUTE VALUE RANGE APPLYING TC EACH LEVEL

               1.0C        4.01       94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3
           ===============================
           .........  CCCCCCCCC  █████████
           .........  CCCCCCCCC  █████████
  SYMBOLS  ....1....  CCCC2CCCC  ████3████
           .........  CCCCCCCCC  █████████
           .........  CCCCCCCCC  █████████
           ===============================
  FREQ.         132         17          4
   1.9 MINUTES ELAPSED TIME FOR HISTCGRAM
   2.1 MINUTES TOTAL PROCESSOR TIME
   0.8 MINUTES TOTAL IO TIME

TIME OF DAY = 12/ 4
```

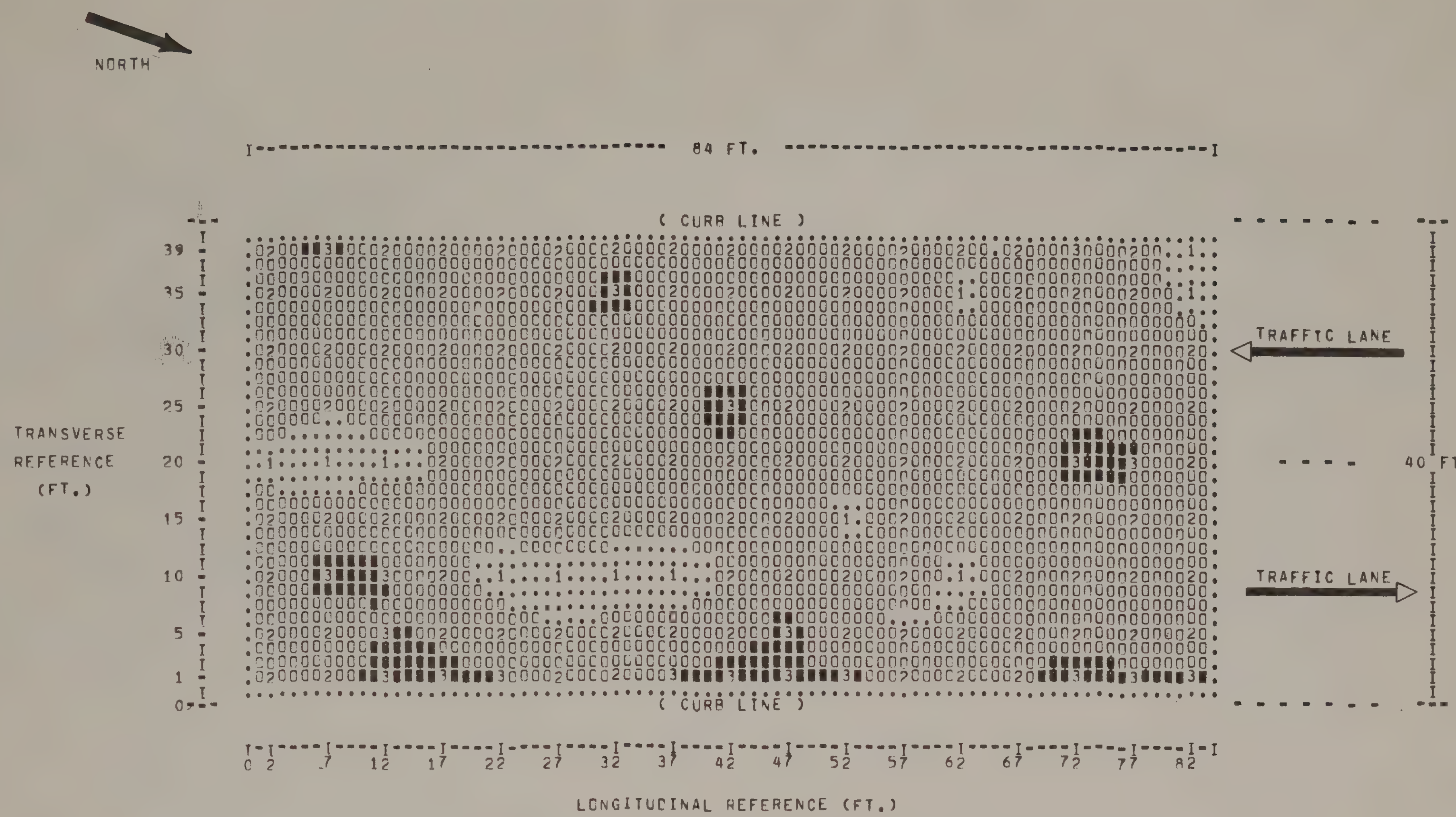

Figure 14 - Corrosion Potential

1977 Survey (In-Service: 1 Year)

TWO-COAT BITUMINOUS EPOXY MEMBRANE

B.I.N. 4453030 SPAN A

SCALE 1 IN. = 10 FT.

```
SYMAP




DATA VALUE EXTREMES ARE          0.12          0.48


ABSOLUTE VALUE RANGE APPLYING TC EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00        0.20        0.36
  MAXIMUM       0.20        0.36        0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TC EACH LEVEL

              25.00       20.00       55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3
          ===============================
           .........  000000000 █████████
           .........  000000000 █████████
  SYMBOLS  ....1....  000020000 ████3████
           .........  000000000 █████████
           .........  000000000 █████████
          ===============================
  FREQ.         12        121        20
   2.0 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.1 MINUTES TOTAL PROCESSOR TIME
   0.8 MINUTES TOTAL IO TIME
TIME OF DAY = 12/21
```

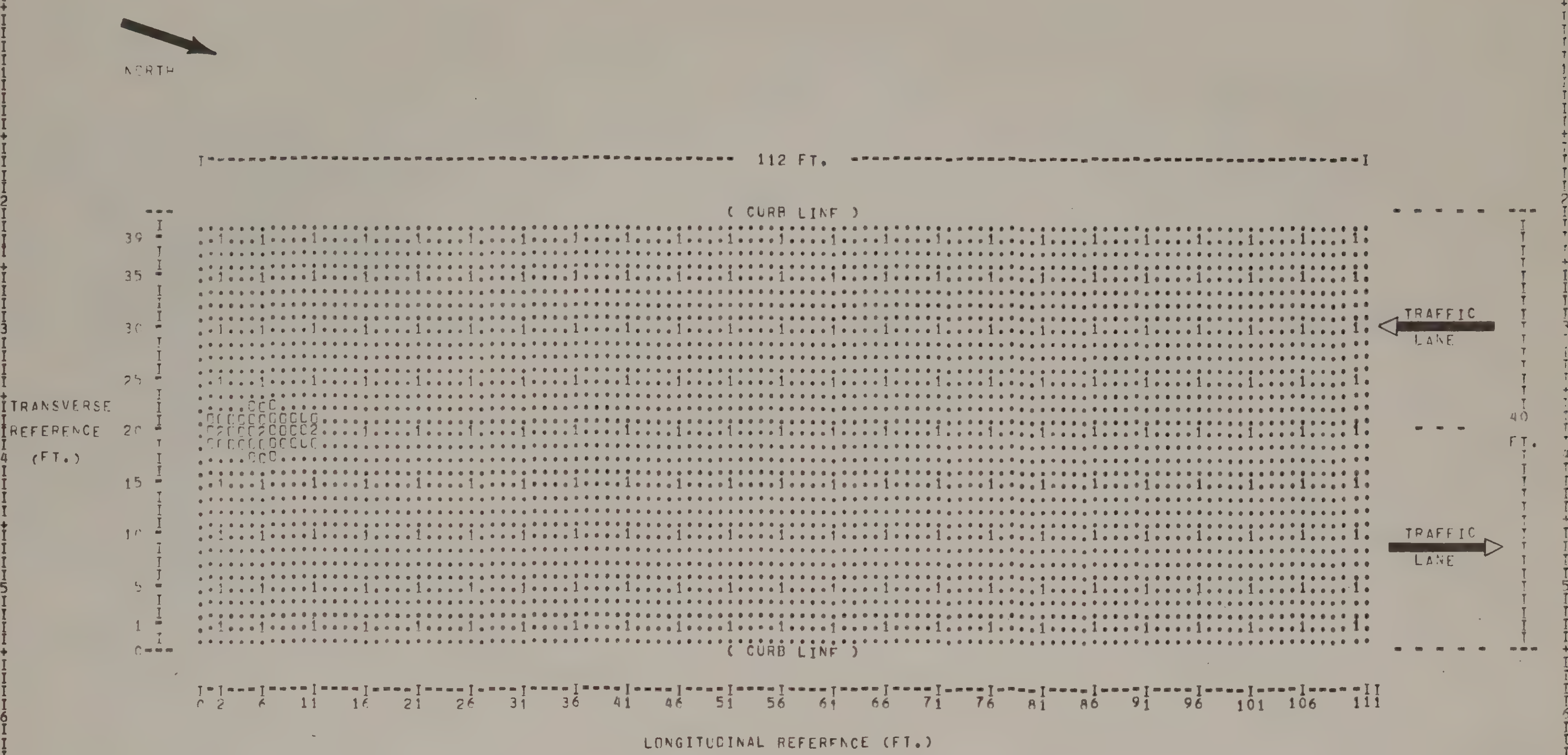

Figure 15 - Electrical Resistance

1977 Survey (In-Service: 1 Year)

TWO-COAT BITUMINOUS EPOXY MEMBRANE

B.I.N. 4453030 SPAN B

SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          2.00       210.00


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM> INCLUDED IN HIGHEST LEVEL ONLY)


  MINIMUM       0.00     100.00    501.00
  MAXIMUM     100.00     501.00  10000.00


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL


               1.00       4.01      94.99


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2          3
           ===============================
            .........  CCCCCCCCC  █████████
            .........  CCCCCCCCC  █████████
  SYMBOLS   ....1....  CCCC2CCCC  ████3████
            .........  CCCCCCCCC  █████████
            .........  CCCCCCCCC  █████████
           ===============================
  FREQ.         204          3          0
   2.5 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.7 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME

TIME OF DAY =  4/ 6
```

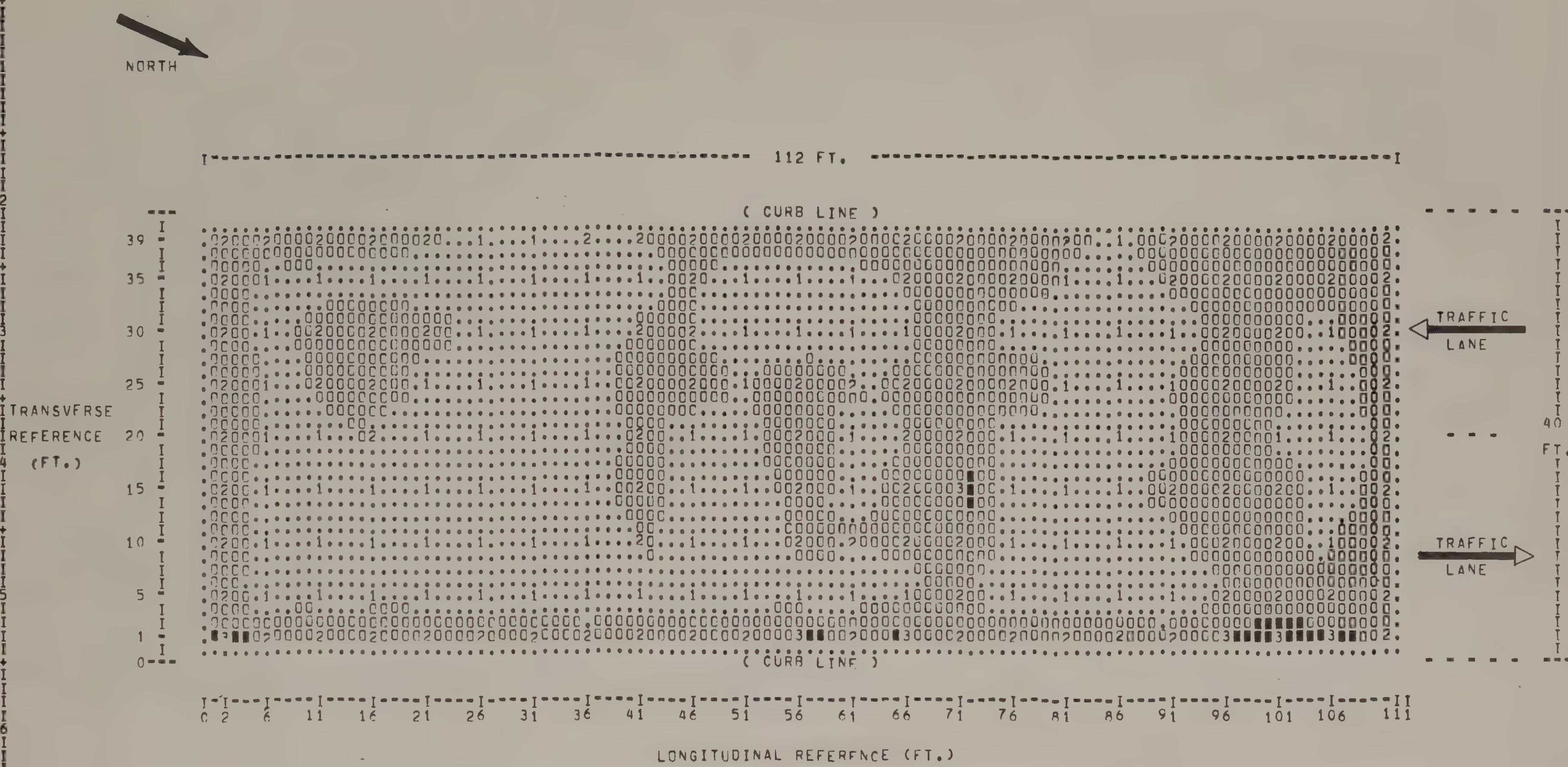

Figure 16 - Corrosion Potential

1977 Survey (In-Service: 1 Year)

TWO-COAT BITUMINOUS EPOXY MEMBRANE

B.I.N. 4453030 SPAN B

SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          0.08          0.44


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3
            ===============================
             .........  OOOOOOOOO  █████████
             .........  OOOOOOOOO  █████████
  SYMBOLS    ....1....  OOOO2OOOO  ████3████
             .........  OOOOOOOOO  █████████
             .........  OOOOOOOOO  █████████
            ===============================
  FREQ.           99        101          7
   2.5 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.7 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME
TIME OF DAY = 12/18
```

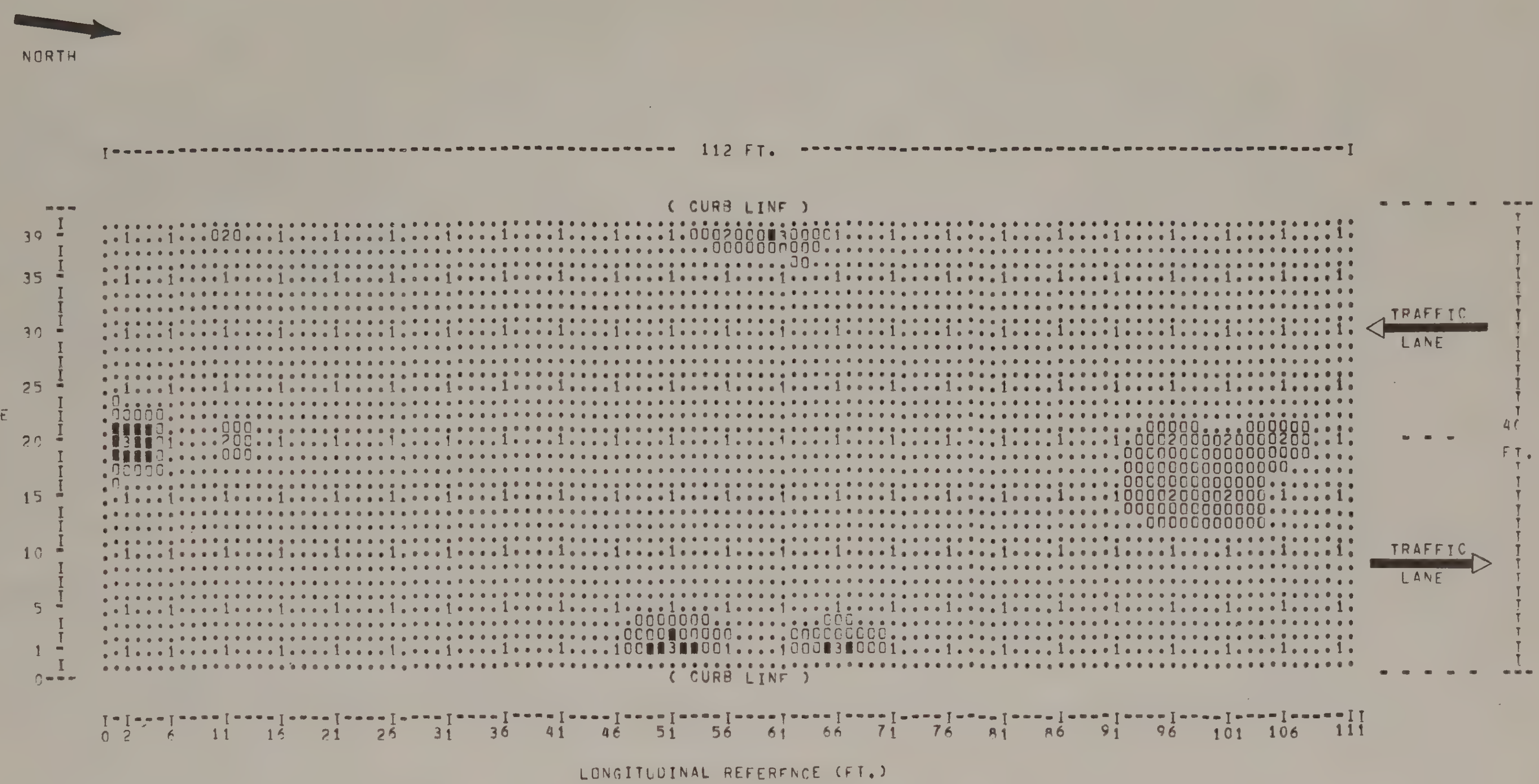

Figure 17 - Electrical Resistance

1977 Survey (In-Service: 1 Year)

NO MEMBRANE TREATMENT

B.I.N. 4453030 SPAN C

SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          2.00      1000.00


ABSCLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00      100.00     501.00
  MAXIMUM     100.00      501.00   10000.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                1.00       4.01      94.99

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
           ===============================
            .........  CCCCCCCCC  █████████
            .........  CCCCCCCCC  █████████
  SYMBOLS   ....1....  CCCC2CCCC  ████3████
            .........  CCCCCCCCC  █████████
            .........  CCCCCCCCC  █████████
           ===============================
  FREQ.        195          8          4
   2.8 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.7 MINUTES TOTAL PROCESSOR TIME
   1.1 MINUTES TOTAL IO TIME
TIME OF DAY =  4/ 3
```

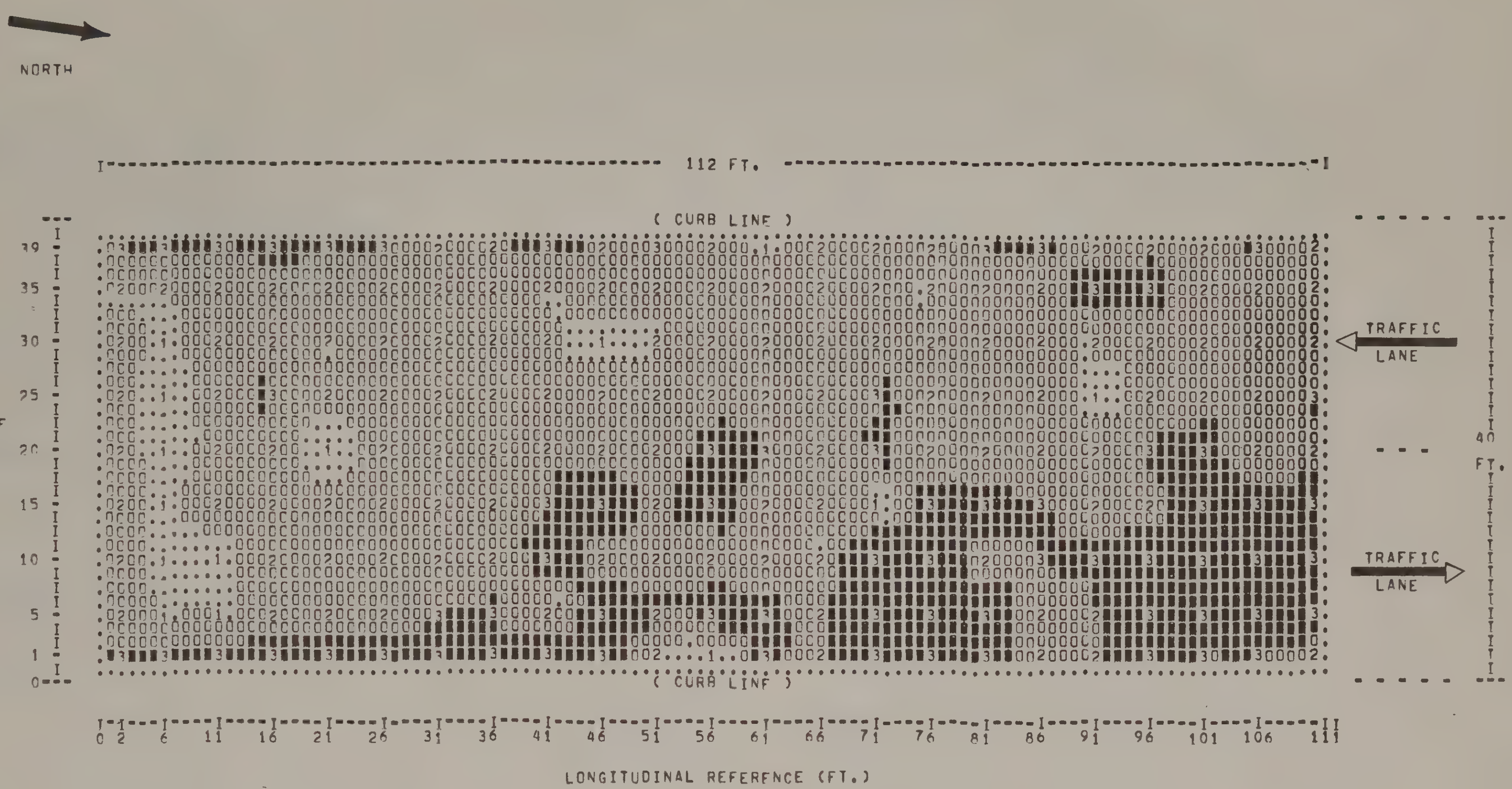

Figure 18 - Corrosion Potential

1977 Survey (In-Service: 1 Year)

NO MEMBRANE TREATMENT

B.I.N. 4453030 SPAN C

SCALE 1 IN. = 10 FT.

```
DATA VALUE EXTREMES ARE          0.02          0.62


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (≥MAXIMUM≥ INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.00       0.20       0.36
  MAXIMUM       0.20       0.36       0.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              25.00      20.00      55.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1         2         3
           ==============================
           ......... 000000000 █████████
           ......... 000000000 █████████
  SYMBOLS  ....1.... 000020000 ████3████
           ......... 000000000 █████████
           ......... 000000000 █████████
           ==============================
  FREQ.          14       125        68
   2.6 MINUTES ELAPSED TIME FOR HISTOGRAM
   2.8 MINUTES TOTAL PROCESSOR TIME
   1.0 MINUTES TOTAL IO TIME
TIME OF DAY = 12/14
```

IV MEMBRANE COSTS

In 1976, each of the preformed sheet membranes (Bituthene; Protecto Wrap; and Royston) was installed on the test structures at a cost of $4.50/s.y. The liquid NEA-4000 LT was also placed at $4.50/s.y. and the bituminous epoxy for $23.85/s.y. These prices included all materials, equipment, and labor to place the waterproofing membrane. They did not include the cost of the wearing course.

In 1977, New York adopted a standard specification for membrane waterproofing. Under these requirements, the contractor is allowed the option of supplying either the Bituthene, Protecto-Wrap, or Royston preformed sheets. Three liquid systems are also optional, but not being studied in this evaluation. Basically, these liquids are high temperature (HT) versions of the NEA-4000 LT that is included in this study. The standard specification does not allow the low temperature liquids at the present time, nor does it allow the use of the bituminous epoxy system.

As a point of interest, nine bridges were reconstructed in 1977 using preformed sheet waterproofing systems. Each of the systems was selected and installed by the contractor under our standard specification requirements. Table 3, shows the types of material and installation costs for the 1977 construction season. Again this cost is for the membrane, equipment, and labor, and does not include the price of overlaying. In general, the installed cost of the preformed sheet systems in 1977, is approximately double the 1976 price.

TABLE 3 - 1977 CONTRACT INSTALLATION COST

CONTRACT NO.	BRIDGE IDENTIFICATION NO.	MEMBRANE TYPE	QUANTITY (s.y.)	INSTALLED COST ($/s.y.)
D95346	1031450	Royston-No.10	1056	8.19
	1031421	"	427	8.19
D95128	1049659	"	787	7.20
	1049649	"	1869	7.20
D95302	1048020	"	856	9.00
D95462	1012890	"	666	15.75
D95395	1019700	"	3000	8.10
D95143	1031580	H.D. Bituthene	734	13.50
D95541	1008320	"	1467	15.75

V SUMMARY

Three preformed sheet and two liquid membrane waterproofing systems are being evaluated for use in bridge deck rehabilitation work. Each system was installed on a test structure in 1976 and overlaid with a 2-1/2 inch thick bituminous wearing course.

The first performance evaluation was made in 1977. At this time each membrane had been in service for approximately one year. On the basis of visual observations and electrical resistance and corrosion potential tests, the three preformed sheet systems (Heavy Duty Bituthene; Royston Bridge Membrane No. 10; and Protecto Wrap M-400A) are performing satisfactorily. The liquid membrane NEA-4000 LT is also satisfactory. The second liquid, a non-proprietary bituminous epoxy membrane appears to be permeable and ineffective as a waterproofing material at this time.

APPENDIX A

MEMBRANE WATERPROOFING MATERIALS

Heavy Duty Bituthene

Heavy Duty Bituthene is a preformed sheet membrane. The preformed sheet is 65 mils thick and composed of a woven polyethylene mesh, coated on one side with a layer of rubberized asphalt. Bituthene Primer and Bituthene Mastic are used in conjunction with the installation. All materials are manufactured by W. R. Grace & Co., Cambridge, Mass.

Protecto-Wrap M-400A

Protecto-Wrap M400A is a preformed sheet membrane, 70±5 mils thick. The preformed sheet is described as being a laminate of aromatic tars, modified with synthetic resins, and reinforced with a synthetic non-woven fabric. Protecto-Wrap #80 Primer and 160H Mastic (or Protecto-Wrap's equivalents) are used in the installation. All materials are manufactured by the Protecto-Wrap Co., Denver, Colorado.

Royston Bridge Membrane No. 10

Royston Bridge Membrane No. 10 is a preformed sheet, 75 mils thick. The preformed sheet is a laminate of reinforced fiberglass mesh and bituminous mastic with a top surface of polyester film. Royston Bridge Membrane Primer 713 and Royston Roskote A-51 Black Mastic are used in the installation. All materials are manufactured by Royston Laboratories, Inc., Pittsburgh, Pa.

NEA-4000 LT, (Low Temperature)

NEA-4000 LT, is a liquid poly-vinyl chloride polymer waterproofing. It is hot applied at application temperatures of from 275-300°F., and at the rate of about 18 s.f./gal. (90 mils). A protective sheet of 65 lb. roofing paper is included in the system to prevent damage in bituminous overlay operations. NEA-4000 LT, is manufactured by POSH Chemical, Inc., Port Washington, N.Y. This liquid system is similar to Superseal-4000 LT (Superior Products Co., Oakland, CA) and WABO-4000 LT (Watson-Bowman Associates, Inc., Buffalo, N.Y.)

Bituminous Epoxy (Two Coat Application)

The bituminous epoxy membrane is a non-proprietary liquid waterproofing system. It consists of a two-component, bituminous modified epoxy resin, applied in two coats (total thickness approximately 100 mils). Stone aggregate is spread in the second coat for adhesion to the bituminous overlay.